# Remote Fireworks Control System

**EN 1190: Engineering Design Project**


Department of Electronic and Telecommunication Engineering
University of Moratuwa

**Team Detonators**

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# Contents

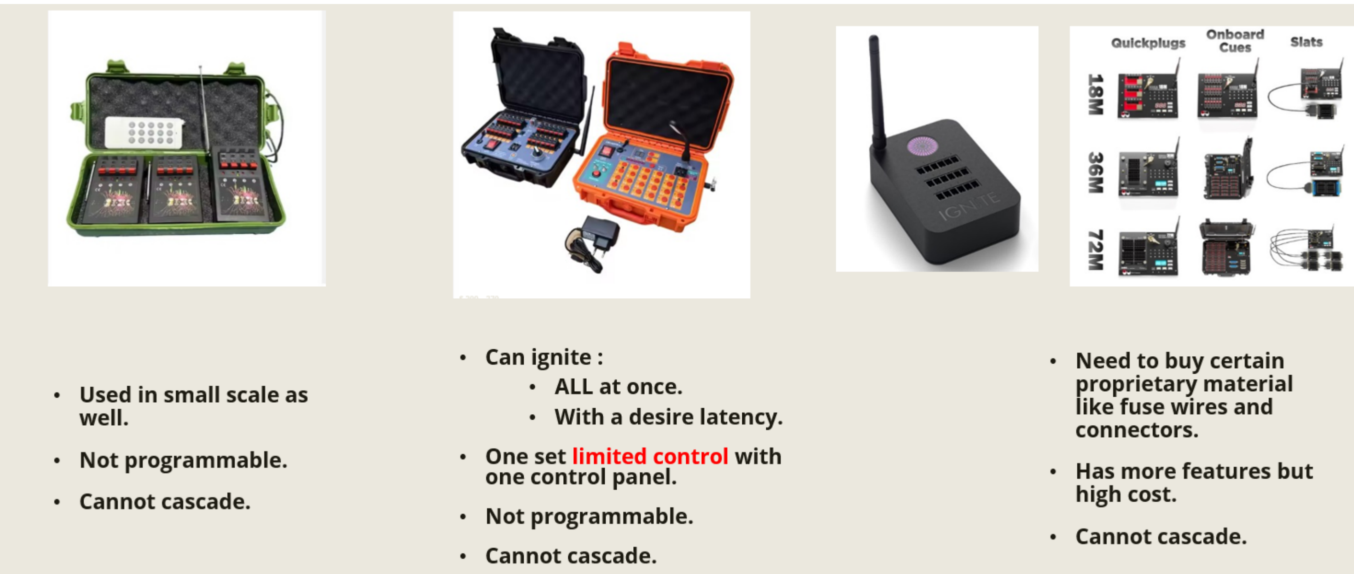
# Problem Statement & Market Analysis

## 1.1 Background

The current market for remote firework detonating systems are basically segmented into three categories based on financial and technical faesability. Thus the consumers in this market select products based on the use case and affordability.

- Low end systems:
  Individual devices with minimum 4 slots. These devices range between USD 15 (LKR 13500 as at 8/7/25) and USD 60 (LKR 18000). These are simple and lack most of control features. But many low end users tend for manual ignition which has very high risk.
- Mid-range systems:
  Provide more features and hence more functionality than low range devices.Cost ranges between USD 200 and USD 300. Limited control with single controller and cannot use custom sequences.
- High end systems:
  Offer more advanced control features but with limited scalability. Additionally they require proprietary consumables like fuse wires which adds onto cost as well. Cost ranges from USD 700.

**Current devices present:**




## 1.2 Problem Description

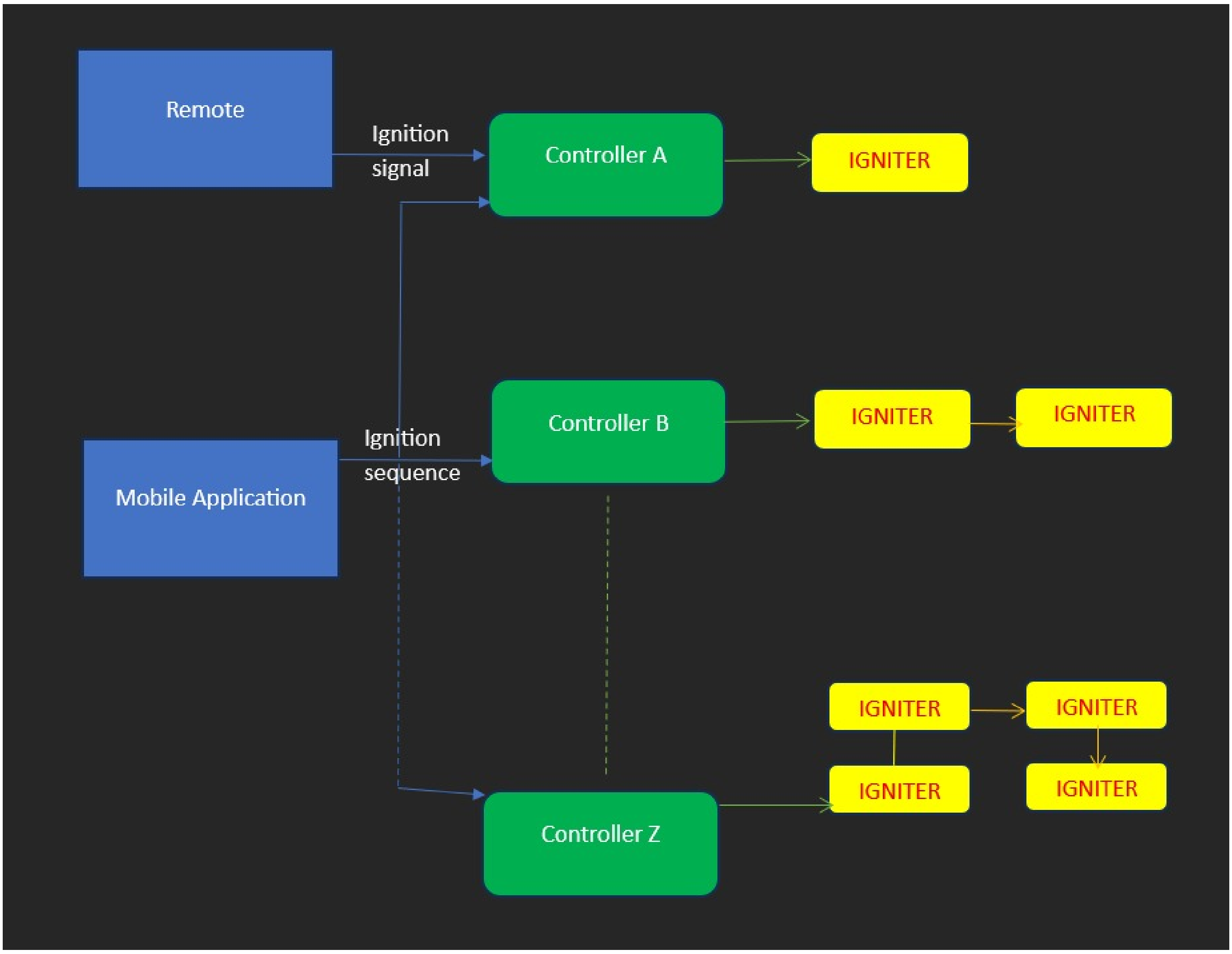
Thereby users in the first two categories cannot afford to buy devices in the third catergory and are limited by control and features. Hence the main goal is to build a scalable and affordable system accessible by all users that include high-end features with more control.

# Proposed Solution Architecture

## 2.1 System Overview

The proposed system has a peer to peer architecture. Hence a controller can control several igniters each having 8 slots. Sets of these controllers can communicate with each other through ESP-Wifi via broadcasting.

Initially, the detonation sequence needs to be sent to controllers from the mobile application. Then when the detonation is initialized from the remote, the system starts the sequence.



## 2.2 Control features

- Scalablility and extendability via cascading.
- Peer to peer architecture that replaces master-slave architecture.
- Broadcasting communication system powered by ESP-Wifi that does not require inidiviudal addressing.
- USB-C cable charging.

## 2.3 Technology Stack

**1. Hardware Layer**

| **Specification** | **Component(s)** |
|---|---|
| Micro-controller | ESP32-WROOM 32U |
| Modules | NRF transceiver, OLED display, 10A 5V relay |
| Power Supply | 3.7V Li-ion batteries, AMS117 3.3V voltage regulator, LM2596S adjustable buck converter, USB-C BMS for 2S battery system |
| Other | 6pin GX16 aviation connectors, network cables,indicator LEDs, SMD resistors and capacitors, |

**2. Software Layer**

| **Specification** | **Description** |
|---|---|
| Firmware | Arduino IDE |
| Protocols / Communication | ESP Wi-Fi (2.4GHz), ESP-NOW protocol, I2C |
| User Interface | OLED display libraries (Adafruit SSD1306), Flutter for mobile UI |
| Mobile application | Dart |
| Development Tools | Altium (PCB design), Fusion 360 (enclosure CAD), Android Studio and Xcode (Mobile app), Git (version control) |

# Product Design and Architecture

## 3.1 Enclosure Design

### Initial Sketches

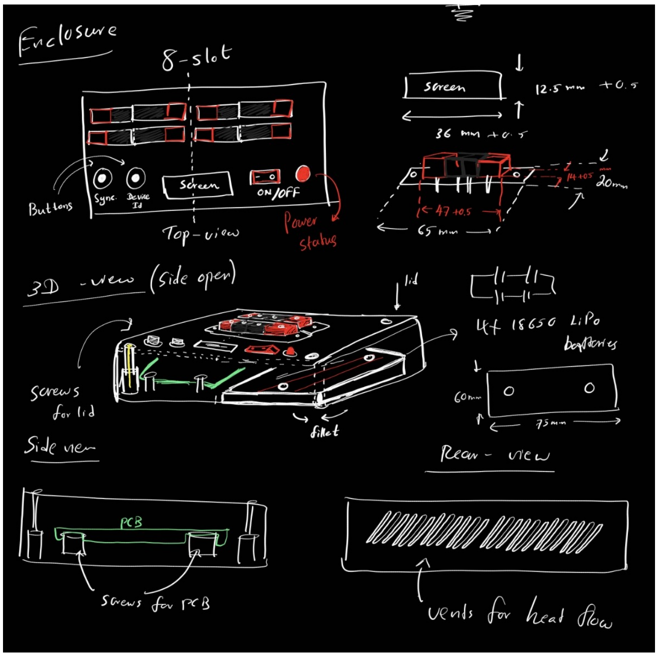



Figure 3.1: Design 1

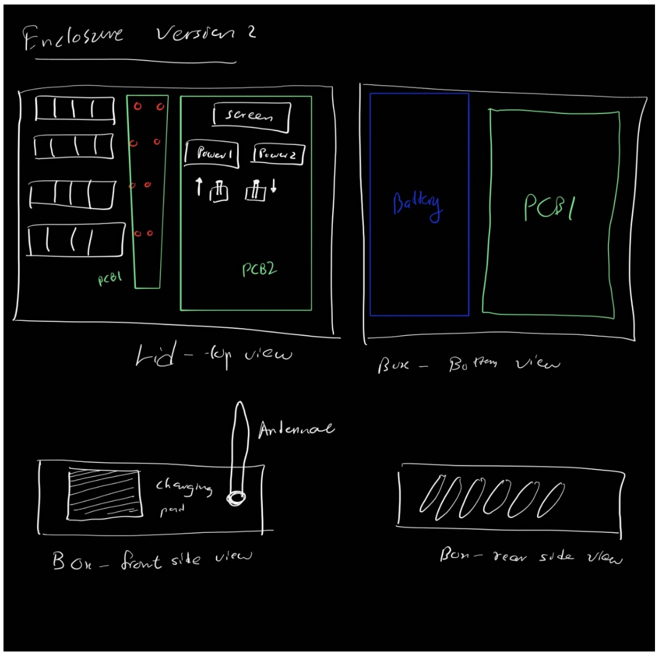



Figure 3.2: Design 2

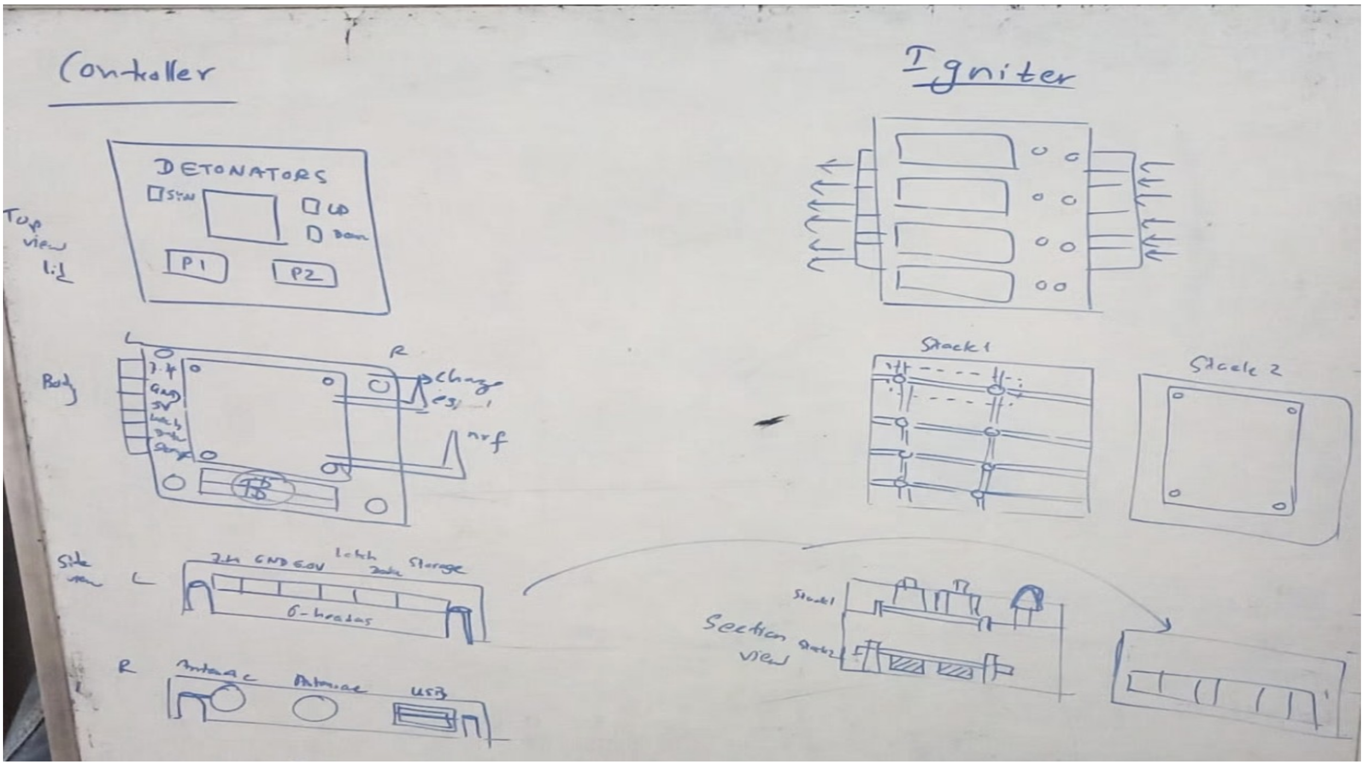



Figure 3.3: Design 3

### Designs and printed enclosures

The enclosure was designed from Fusion 360. Initially the plan was to design a single device, but at design stage 3 the controller and igniter were decided to be designed as two separate devices. This now allows the user to cascade igniters to the controller as per requirement.

The enclosures were printed with the material PLA, after trying a transparent material as well, which did not give the expected results.

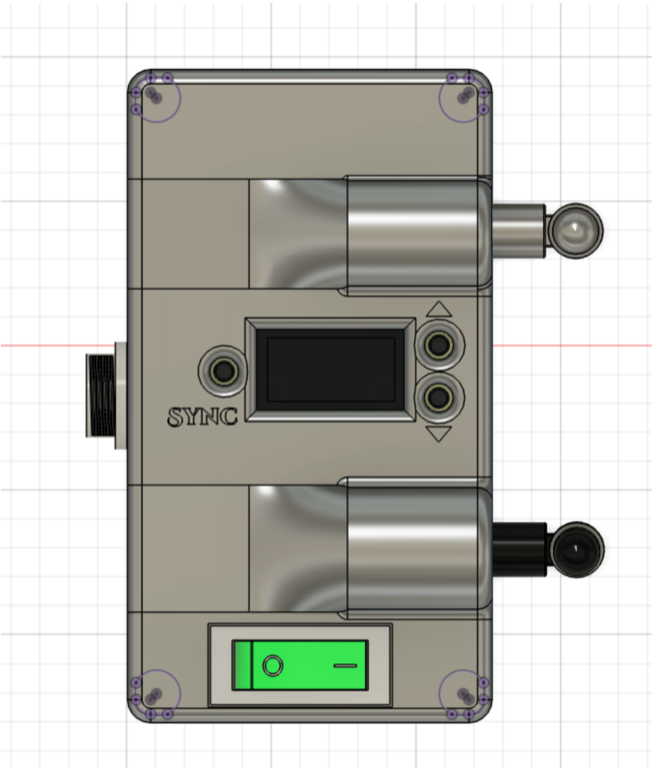



Figure 3.4: Top view of controller


Figure 3.5: Top view of igniter

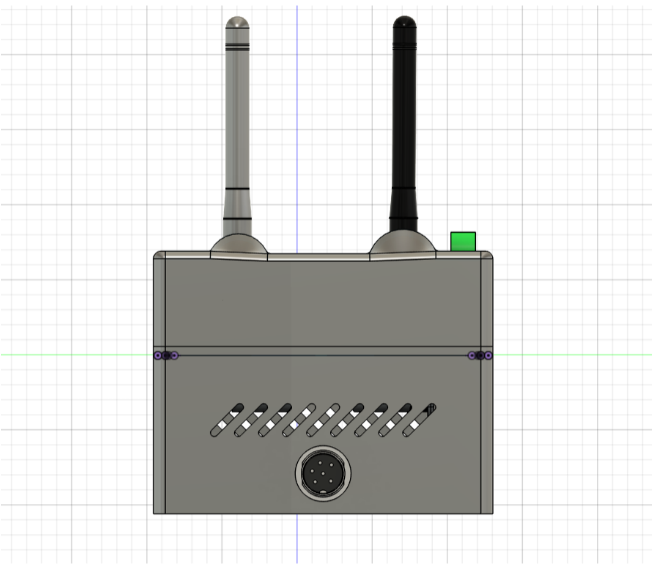


Figure 3.6: Left view of controller

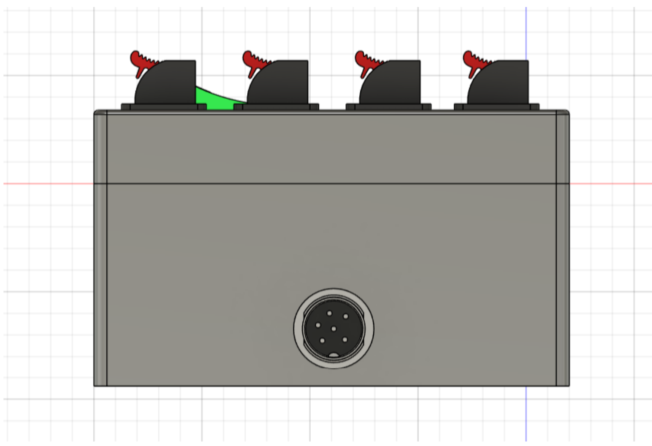


Figure 3.7: Left view of Igniter

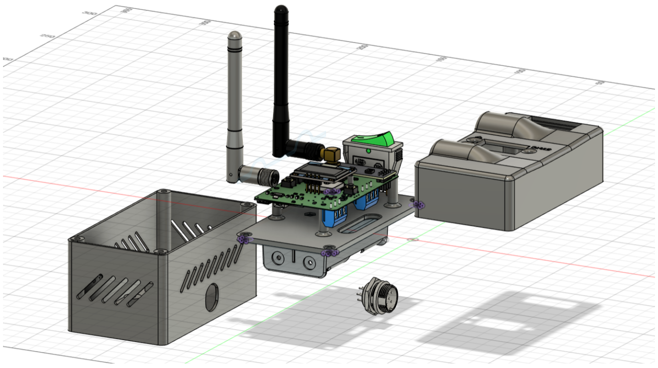


Figure 3.8: Exploded view of controller

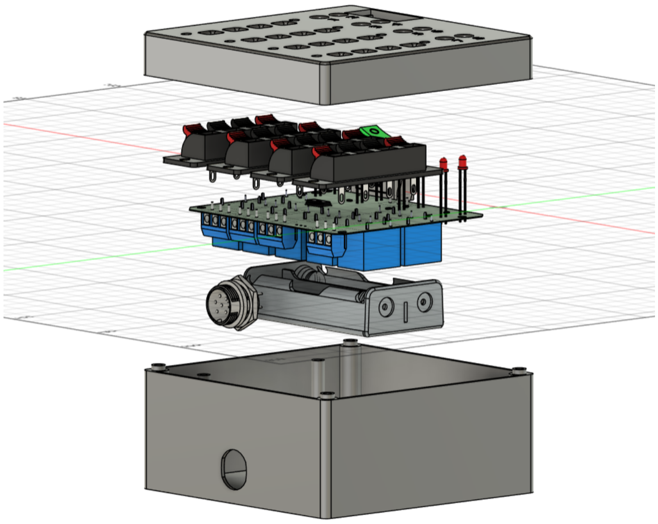


Figure 3.9: Exploded view of igniter

Figure 3.10: Printed enclosures

## 3.2 PCB Hardware Design

While fulfilling the main requirement of igniting the fusing wire, several other factors were considered in PCB design as well.

- Power management due to high current.
- Uninterrupted signal transmission.
- Safety of user.

## Design sketches for PCB

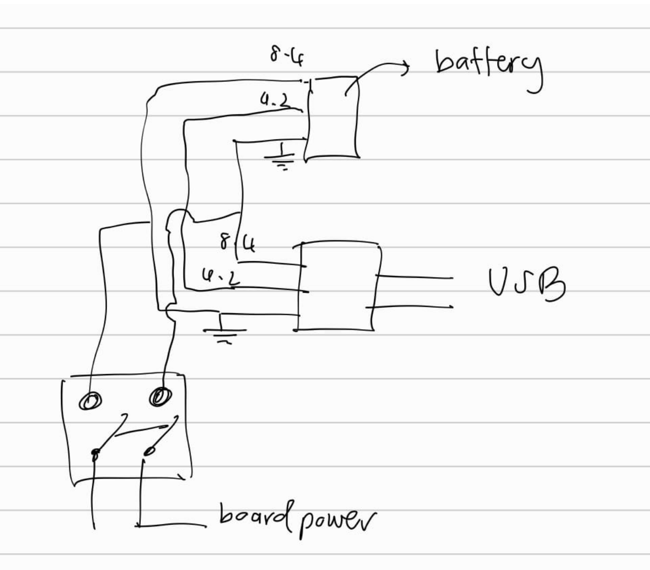



Figure 3.11: Power design sketch

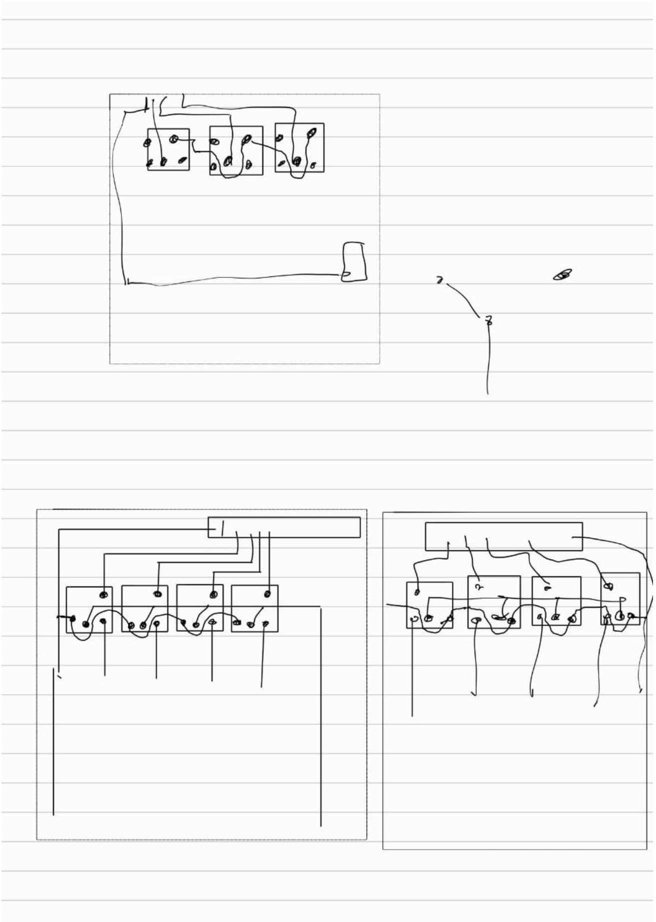


Figure 3.12: Relay design sketch

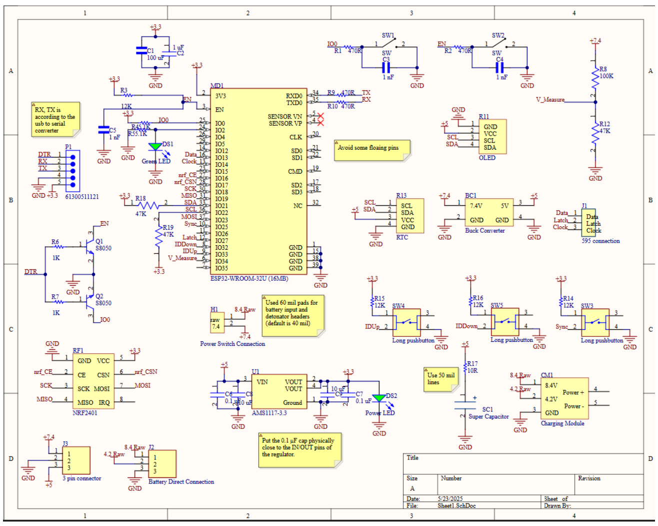


Figure 3.13: Controller schematic

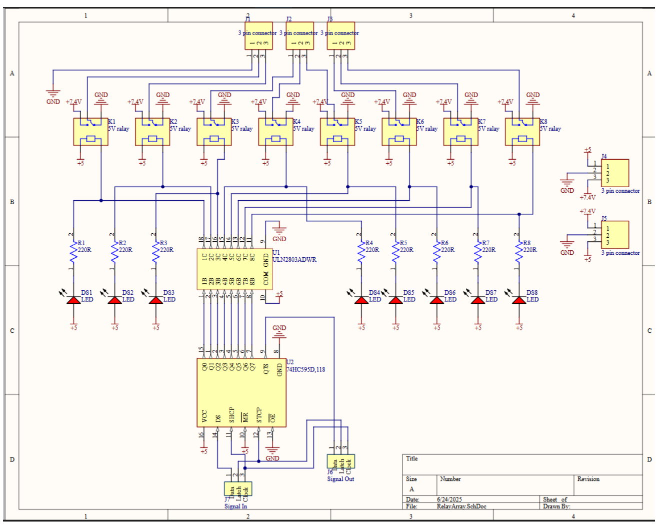


Figure 3.14: Igniter schematic

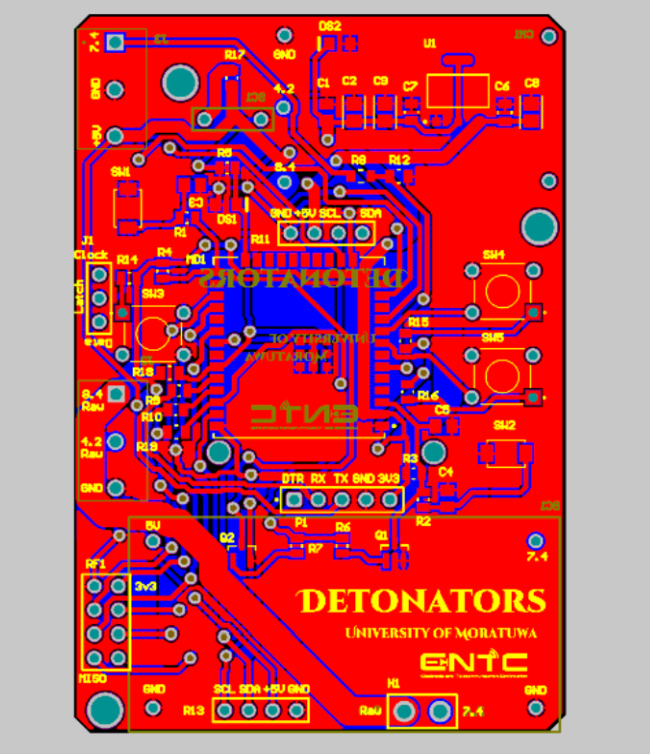



Figure 3.15: Controller PCB

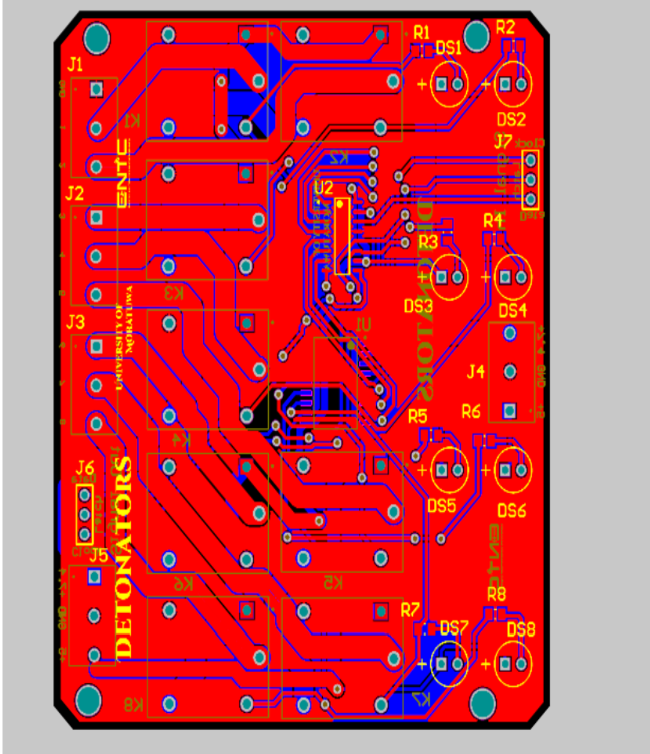



Figure 3.16: Igniter PCB

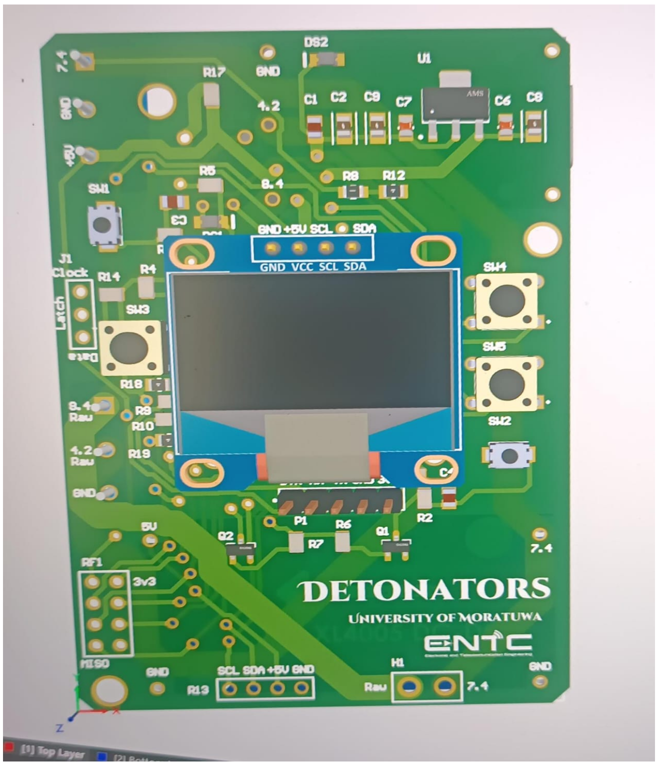



Figure 3.17: Controller PCB 3D model

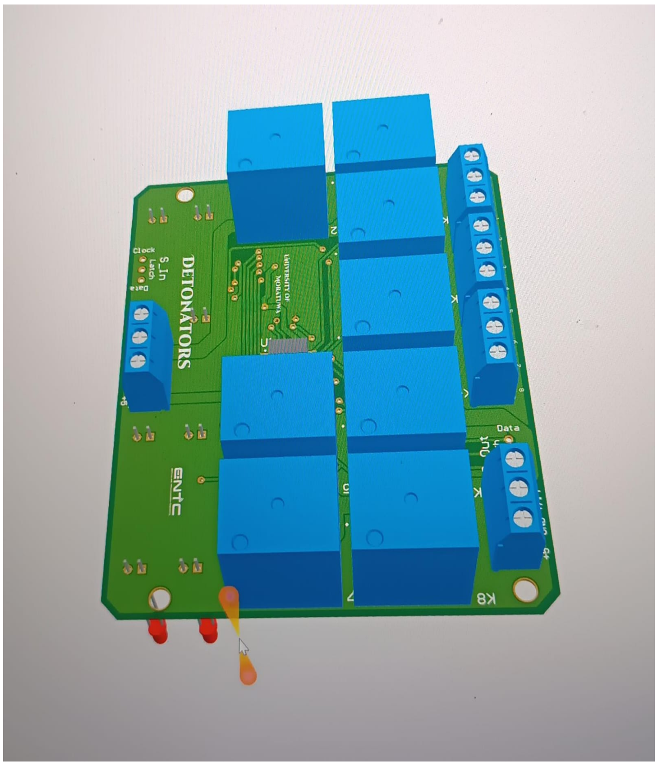



Figure 3.18: Igniter PCB 3D model

## 3.3 Software Design

### Micro-controller firmware

```
mainn.ino    choose.ino    get_hash.ino    globals.h    ignition.ino    show_seq.ino

}

void checkAndRunTask() {
  while (portTimeDict[cindex].letter == MY_DEVICE_ID) {
    Serial.printf("Running task for index %d\n", cindex);
    turnOffAllRelays();
    delay(10);
    int relaySlot = portTimeDict[cindex].number1 - 1;
    setSlot(relaySlot, true);


    // Show index on OLED
    display.clearDisplay();
    display.setTextSize(1);
    display.setCursor(0, 10);
    display.println(cindex);
    display.display();

    Serial.println("Slot set to ON!");
    delay(portTimeDict[cindex].number2);

    cindex += 1;
  }

  broadcast(cindex);
}

void setSlot(int slot, bool state) {
  if (state)
    outputState |= (1 << slot);
  else
    outputState &= ~(1 << slot);
  updateShiftRegister();
}
```

Figure 3.19: figure
Firmware architecture

This system is a distributed wireless fireworks ignition controller built using multiple ESP32 devices. Each device is assigned a unique identifier (such as A, B, C, etc.) during startup using onboard buttons and an OLED screen.

Before operation begins, a predefined ignition sequence is uploaded to each device individually. This sequence is stored as a hash map (dictionary) containing a list of ignition steps. Each step specifies:

- which device should perform the ignition,
- which relay slot to activate,
- and for how long the relay should remain on.

Every device receives and stores the complete ignition sequence locally.

The ignition process starts when a trigger signal is received via an NRF24 module—typically by device A. That device begins checking the sequence from the beginning and carries out all ignition steps assigned to it. When it encounters a step that belongs to another device, it broadcasts the corresponding index of that step to all devices using ESP-NOW.

All devices receive the broadcast. The one responsible for the given ignition index sends back an acknowledgment (ACK) and proceeds with its own ignition steps. Once it completes its section of the sequence, it broadcasts the next relevant index, and the process continues.

After broadcasting, a device waits for a short period (e.g., 400 ms) for an ACK. If none is received, it retries broadcasting up to a few times. This ensures reliable communication even in wireless environments.

Devices ignore ignition indices that have already been processed or are too old, avoiding duplication. Each relay is controlled through a shift register, and an OLED display shows the current ignition index being handled.

Through this cooperative broadcasting and acknowledgment process, the entire ignition sequence is executed in the correct order across multiple devices without the need for a central controller.

## Mobile application

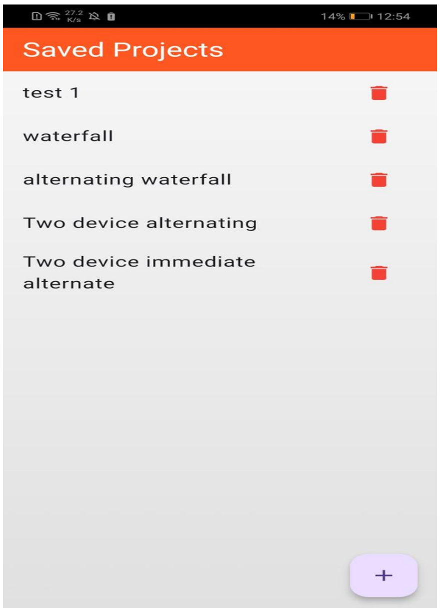



Figure 3.20: Pre-saved sequences

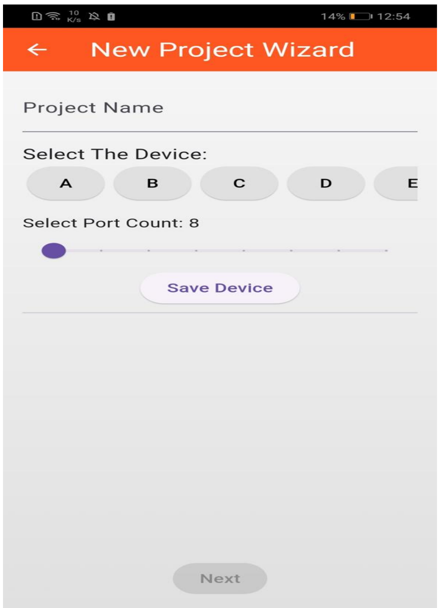



Figure 3.21: Device addition

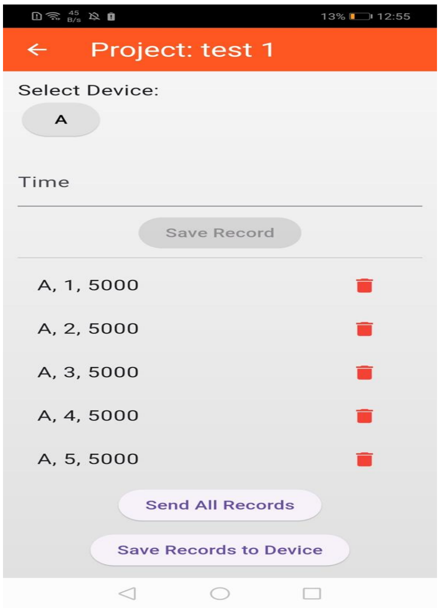



Figure 3.22: Sequence creation

The mobile application was designed to transmit the ignition sequence to the controller as per user requirements. It was built using the Flutter framework with the Dart programming language, ensuring cross-platform compatibility. Android Studio was used for testing and the app was successfully built for the Android devices. Xcode was used for testing on iPhones, and the iOS version of the app is currently under development.

# From prototype to Final product

## 4.1 Prototyping and Testing

- The initial prototype that included the shift register IC was tested with fusing wires made of Nichrome and matchsticks. The signals were sent from the shift register and were sent to MOSFETS prior to relays. Because it took a long time for the fusing wires to ignite, it was decided not to use MOSFETs.
- Due to a technical fault in the NRF transceiver module, a remote was used as an alternative to give the initiation signal to the controller.

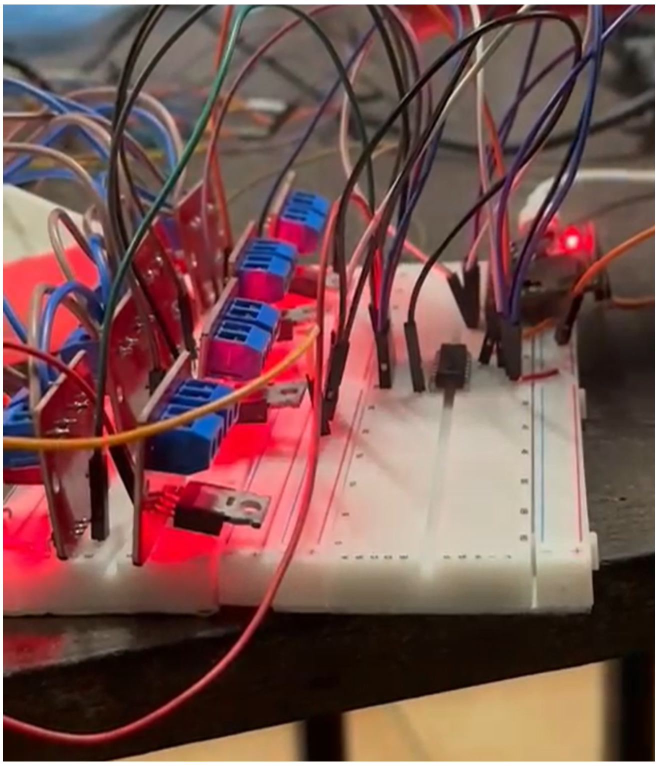


Figure 4.1: Prototyping with MOSFETs

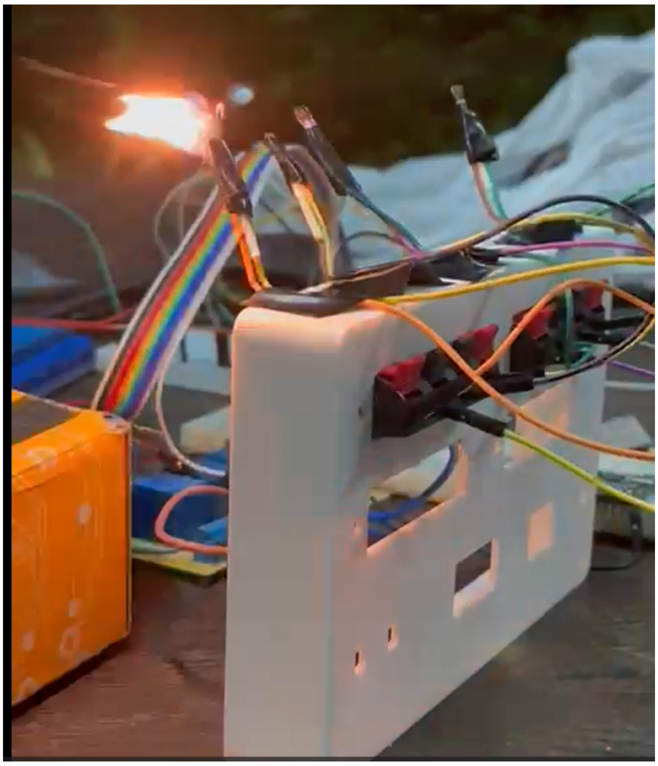


Figure 4.2: Prototype successful with relays

## 4.2 Final product

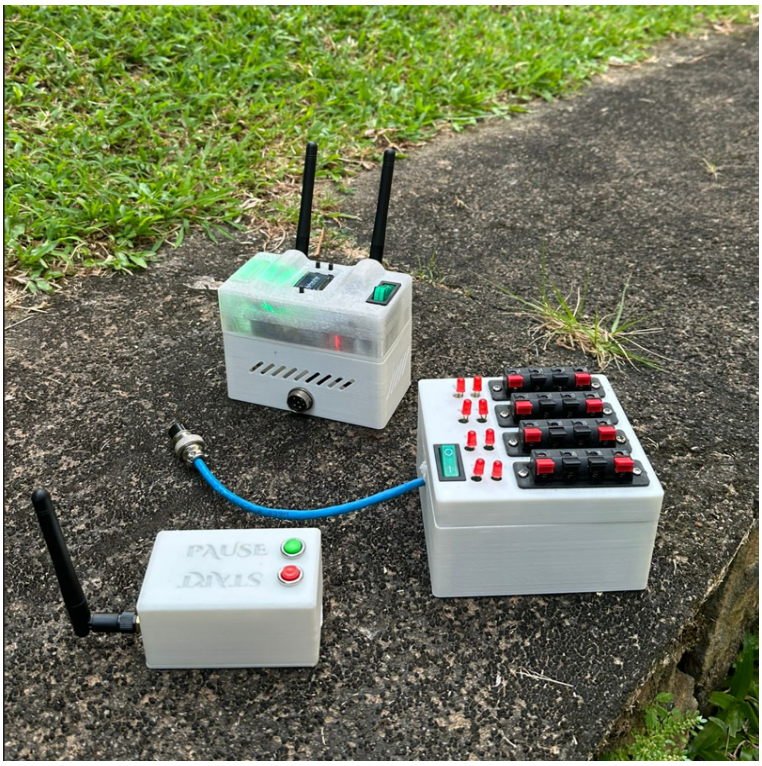



Figure 4.3: A single controller with a single igniter

## 4.3 Stakeholder involvement

Prior to design several small and medium scale stakeholders in the firework industry were contacted and possible product designs were discussed. Three professionals were interested.

- Ruhunu fireworks.
- South Lanka fireworks.
- Alidon fireworks.

Final product was successfully tested under the supervision of Ruhunu fireworks for an event at Waters Edge Hotel, Battaramulla.

Figure 4.4: Testing at Waters Edge Hotel

Figure 4.5: Mr.Pathum from Ruhunu Fireworks and the team

# Budget Analysis and Cost Estimation

## 5.1 Component Costs

| PCB | Comment | Unit Price($) | Quantity per one(units/g) | Total cost per unit |
|---|---|---|---|---|
| Controller | 50V 1nF C0G ±5% 0805 Multilayer Ceramic Capacitors MLCC - SMD/SMT ROHS | $0.00820 | 3 | $0.02460 |
| | Emerald 0805 LED Indication - Discrete ROHS | $0.01100 | 2 | $0.02200 |
| | 75dB@(120Hz) 1A Adjustable Positive electrode 16V SOT-223 Voltage Regulators - Linear, Low Drop Out (LDO) Regulators ROHS | $0.19520 | 1 | $0.19520 |
| | 25V 10uF X5R ±10% 0805 Multilayer Ceramic Capacitors MLCC - SMD/SMT ROHS | $0.01070 | 2 | $0.02140 |
| | 125mW Thick Film Resistors 150V ±1% ±200ppm/°C 10Ω 0805 Chip Resistor - Surface Mount ROHS | $0.00160 | 1 | $0.00160 |
| | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 12kΩ 0805 Chip Resistor - Surface Mount ROHS | $0.00190 | 4 | $0.00760 |
| | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 1kΩ 0805 Chip Resistor - Surface Mount ROHS | $0.00170 | 2 | $0.00340 |
| | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 470Ω 0805 Chip Resistor - Surface Mount ROHS | $0.00190 | 4 | $0.00760 |
| | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 47kΩ 0805 Chip Resistor - Surface Mount ROHS | $0.00190 | 3 | $0.00570 |
| | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 5.1kΩ 0805 Chip Resistor - Surface Mount ROHS | $0.00180 | 2 | $0.00360 |
| | 160V 225mW 80@10mA,5.0V 600mA NPN SOT-23 Bipolar (BJT) ROHS | $0.02500 | 2 | $0.05000 |
| | 6.3V 100uF X5R ±20% 0805 Multilayer Ceramic Capacitors MLCC - SMD/SMT ROHS | $0.25270 | 1 | $0.25270 |
| | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 100kΩ 0805 Chip Resistor - Surface Mount ROHS | $0.00190 | 1 | $0.00190 |
| | ESP32-WROOM-32U (16MB) SMD,18x19.2mm WiFi Modules | $3.94540 | 1 | $3.94540 |
| | 100V 1uF X7S ±10% 0805 Multilayer Ceramic Capacitors MLCC - SMD/SMT ROHS | $0.04660 | 1 | $0.04660 |
| | 0V 100nF X7R ±10% 0805 Multilayer Ceramic Capacitors MLCC - SMD/SMT ROHS | $0.00340 | 2 | $0.00680 |
| | Without bracket 50mA 4mm 100000 Cycles 12V 1.6N 3mm 2mm Round Button Vertical welding SPST SMD Tactile Switches ROHS | $0.03970 | 2 | $0.07940 |
| | LM2596S 3-40V to 1.5-35V 4A DC to DC Adjustable Step-Down Buck Module | $0.60000 | 1 | $0.60000 |
| | 0.96 inch 128X64 OLED Display Module Blue I2C IIC (DM0037) | $1.97670 | 1 | $1.97670 |
| | Enclosure | $0.01800 | 112.09 | $2.01762 |
| | Battery Holder Case for 2x18650 | $0.20000 | 1 | $0.20000 |
| | Type-C USB 2/3S BMS 15W 8.4V 12.6V 1.5A Lithium Battery Charging Boost Module With Balanced Support Fast Charge With Indicator | $2.29000 | 1 | $2.29000 |
| | IPEX to SMA Cable WIFI 3G 4G GSM Female Wire | $0.67000 | 1 | $0.67000 |
| | Adjustable Digital Antenna for Wifi Routers 2.4Ghz 3dBi | $1.00000 | 1 | $1.00000 |
| | NRF24L01+PA+LNA 2.4G Wireless Transceiver Module with SMA Antenna | $2.00000 | 1 | $2.00000 |
| | 3.7V 3200mA 18650 Li-ion Rechargeable Battery | $1.76000 | 2 | $3.52000 |
| | PCB | $0.79000 | 1 | $0.79000 |
| Igniter | 125mW Thick Film Resistors 150V ±100ppm/°C ±1% 200Ω 0805 Chip Resistor - Surface Mount ROHS | $0.00190 | 8 | $0.01520 |
| | OCTAL 50V 500mA SOP-18-300mil Darlington Transistor Arrays ROHS | $0.15260 | 1 | $0.15260 |
| | 8 2V~6V 1 Serial to serial or parallel SOIC-16 Shift Registers ROHS | $0.09660 | 1 | $0.09660 |
| | 250V@AC 5V 15A 1 Form B: 1B (SPST-NC) Through Hole,15.6x19.2mm Power Relays ROHS | $0.32400 | 8 | $2.59200 |
| | Enclosure | $0.01800 | 105 | $1.89000 |
| | PCB | $1.68400 | 1 | $1.68400 |
| | Battery Holder Case for 2x18650 | $0.20000 | 2 | $0.40000 |
| | 3.7V 3200mA 18650 Li-ion Rechargeable Battery | $1.76000 | 1 | $1.76000 |
| | 20mA 80mcd Diffused Red Lens 624nm -40°C~+85°C Red 45° 3mm Round Lens 60mW 2V Through Hole,D=3mm LED Indication - Discrete ROHS | $0.03000 | 8 | $0.24000 |
| | **Total direct cost for controller per unit** | **$19.73982** | | |
| | **Total direct cost for relay array per unit** | **$8.83040** | | |

Figure 5.1: Direct Cost

| | | price($) | avg no of units can be used for | per unit cost |
|---|---|---|---|---|
| Indirect Materials | Solder Paste | 2.63 | 20 | $0.13150 |
| | solder flux | 1.6 | 20 | $0.08000 |
| | Isopropyl Alcohol | 1.1 | 20 | $0.05500 |
| | solder wire | 11.58 | 20 | $0.57900 |
| | Cotton Swabs | 0.67 | 50 | $0.01340 |
| | Import tax + warehouse | 16.3 | 10 | $0.32600 |
| Indirect Machine/Tool Costs | Soldering Iron Tip | 3.02 | 30 | $0.06040 |
| R&D cost | | | | |
| Estimated no of products to sell | 10 | | | |
| **Materials** | **cost per unit** | **no of units** | **total cost** | |
| test enclosures | | | $3.80 | $0.38000 |
| test pcbs | | | $14.59 | $1.45900 |
| ESP32-WROOM-32U Dev Board | 3.83 | 4 | $15.32 | $1.53200 |
| Additional Components (mosfets,led arrays,etc) | | | $20.00 | $2.00000 |
| | | | Total indirect cost per unit | $6.61630 |

Figure 5.2: figure
Indirect Cost

## 5.2 Final Product Pricing

| | | |
|---|---|---|
| Total direct cost for the controller per unit | $19.7398 | |
| Total direct cost for igniter per unit | $8.8304 | |
| Total indirect cost per unit | $6.61630 | |
| | | in LKR |
| Total cost for controller per unit | $26.3561 | LKR 7,906.84 |
| Total cost for igniter per unit | $15.4467 | LKR 4,634.01 |
| dollar to lkr rate | 300 | |
| Markup | 50.00% | |
| **Final price** | **Controller** | **LKR 11,860.25** |
| | **Igniter** | **LKR 6,951.02** |

Figure 5.3: Total cost and pricing

# Team Contributions.

## 6.1 Individual Contributions

- Peiris T.S.R. - 230470U (Team lead):
  - Designed the program to control the ESP32 chip accordingly for signal transmission and the remote for ignition initiation.
- Palihena H.H. - 230458P:
  - Built the mobile application for sequence generation and transmission for the controller via WiFi.
- Kariyawasam J.H.D - 230318M:
  - Designed the schematics and the PCB for proper functionality of the system aligned with stakeholder requirements and designed the controller enclosure.
- Gunasekara L.U.A. - 230212H:
  - Designed the prototype with shift registers, that act as an 8 bit switching circuit triggered by input signal, designed the igniter enclosure and carried out documentation.

All team members equally contributed for prototype testing, soldering SMD components, assembling and testing the final product.